The Application of the QBR Index to the Riparian Forests of Central Ohio Streams

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Introduction

A riparian area is defined as the transitional zone between a river or stream and the adjoining terrestrial upland ecosystem, including both the stream channel itself and the surrounding land that is influenced by fluctuating water levels (Corbacho *et al.* 2003, Goebel *et al.* 2003). Although forested riparian areas occupy only around 1.4% of the earth's total landscape, they are important both ecologically and economically (Sweeny *et al.* 2002). These forested areas support high biodiversity, provide water quality protection, naturally control floods, stabilize stream banks, provide important wildlife habitat, and allow for direct human benefits such as recreation and aesthetics (Carver *et al.* 2004; Corbacho *et al.* 2003; Greenwald and Brubaker 2001; Opperman and Merenlender 2000; Tockner and Stanford 2002). Although all of the services provided by these ecosystems are critical ecological functions, riparian forests are among the most threatened ecosystem types in the world (Tockner and Stanford 2002; Alpert *et al.* 1999).

Degradation of riparian forests occurs for many reasons. Riparian areas are subjected to several natural disturbance types, e.g., flooding, fire, wind, insects, and diseases. Humans have introduced disturbances into this ecosystem type and have also altered the natural disturbance regimes (Miller *et al*. 2006; Yates *et al*. 2004). The building of dams creates a loss of the natural vegetation, loss of floodplains, and altered flooding cycles for the area directly affected and also the floodplain below the dam (Friedman and Scott 1995).

Agricultural practices have resulted in the complete loss of riparian forests in many cases, and in other cases result in a severe reduction in the width and perceived "quality" of the forests. Floodplain areas are generally rich in nutrients with well-developed soils and high moisture content, making them ideal not only for woody vegetation growth, but also for growing crops

(Knutson and Klass 1998). Therefore, the forests along creeks and streams are often either totally removed, or only a thin buffer strip remains thereby increasing the acreage in crop production. This reduction in canopy cover over the streams and the introduction of runoff chemicals such as fertilizers can result in increased algal and macrophyte production within the streams, which can slow flow rates, block the stream channel, and further lower the water quality (Bunn *et al*. 1999).

Grazing of animals in riparian forests is another practice that can degrade this ecosystem type. Seedlings and saplings are browsed, resulting in reduced or eliminated regeneration, which can ultimately result in total loss of wildlife habitat if continued for long periods of time. Grazing may also result in stream bank erosion, which decreases the area of the floodplain, pollutes stream waters, and leaves steep, undercut banks that continue to erode over time (Lowrance and Vellidis 1995).

Channelization of streams and rivers is one of the primary anthropogenic disturbance types in riparian forests (Raven *et al*. 1998). Streams are altered from their natural streambed to direct the flow of water to achieve the management objectives desired by the landowner. Reasons for channelizing a stream or river are varied, including increased speed of runoff, increased runoff capacity, increased area for agriculture, increased area for development, flood control, easier navigation, and ease in extracting water for consumption.

The disturbance caused by channelization affects almost every aspect of the stream. Natural habitat areas are lost, and the resulting habitat following the channelization is often unsuitable for many of the original species that lived within the stream channel. Water quality is generally decreased, as erosion increases, stream velocity increases, and water temperatures are elevated. The riparian forests are also degraded or removed entirely, for either the initial construction of the channel, or for maintenance of the channel following its establishment (Salinas *et al*. 2000).

In addition to anthropogenic disturbances, there are many natural types of disturbances in riparian forests, which are vital to the maintenance of high biodiversity and high habitat quality. Flooding, wind, fire, non-native plants, insects, and diseases are all causes of disturbance in forest ecosystems, however, the most prevalent type in riparian forests is flooding (Suzuki *et al*. 2002). Although many species of trees and shrubs are able to establish seedlings and maintain saplings in floodplain zones, only those species with high flood tolerances are able to survive to maturity. These tree species include boxelder (*Acer negundo*), swamp white oak (*Quercus bicolor*), green ash (*Fraxinus pennsylvanica*), American sycamore (*Platanus occidentalis*), and eastern cottonwood (*Populus deltoides*).

Periodic flooding occurs naturally along streams and rivers, and flood-tolerant species are often dependent on the floods to maintain dominance in the canopy and to limit the regeneration of flood intolerant species. Much of the diversity in the woody plants in riparian forests is the result of flooding cycles and the dynamic nature of floodplain areas (Lyon and Gross 2005). Diversity in both tree and shrub species and in structure yields a similarly high diversity in the microhabitat types present, which often results in high wildlife diversity as well (Gabbe *et al*. 2002). Native plant species richness is often decreased by non-native plants (Colton and Alpert 1998; Holl and Crone 2004; Siemann and Rogers 2001); exotic species are often the most prevalent in fragmented forest areas and buffer strips along streams (Borgmann and Rodewald 2005)

Disturbance regimes in these forests have often been altered by humans, which can affect the riparian habitat. Flooding has been either eliminated or worsened in streams and rivers.

Flooding may cease as the result of the construction of a dam, the conversion of a naturally flowing stream into one that is run underground through an urban development, or through the building of levies and dikes. Floods can also be exasperated by many of these same disturbance types (Knutson and Klass 1998). When the water held by a dam is released due to high water levels, the resulting flood downstream is often more destructive than the original floods that affected the area would have been. Dikes and levies may not hold, releasing more water than the stream would normally hold at that point in the floodplain. Agriculture and development along streams may not always increase the amount or severity of flooding, but there may be increased potential monetary losses from the floods (Tockner and Stanford 2002).

Many restoration projects have been undertaken in riparian forests, but until recently, no easy-to-use field method for assessing the quality of riparian areas has been created. Indices for assessing water quality of streams and rivers based on the properties of the water itself, its biological communities and its geomorphic features (Newson *et al*. 1998; Raven *et al*. 1998) have been developed, but very few indices exist to assess forests along streams (Munné *et al*. 2003).

The QBR index ("Qualitat del Bosc de Ribera" or "Riparian Forest Quality") is an easy-to-use field method for assessing the habitat quality of riparian forests. It was designed and developed for use in Mediterranean streams in Spain (Munné *et al*. 2003). The index is based upon four main aspects of the riparian area being studied. A score is generated that can then be used to contrast sites, to compare sites to ideal conditions, or to assess the success of restoration projects over time. The four main aspects of the QBR index are: total vegetation cover, vegetation cover structure, cover quality, and channel alterations. Once scores have been calculated, they can be used in rehabilitation, restoration, or preservation projects in watershed planning, or in the general management of riparian forests.

In this study, we adapted the QBR index for use in central Ohio watersheds. The following specific objectives for the project are:

1) Alteration of any terms and requirements of the index that are region-specific to the Mediterranean area,
2) Development of lists of native and of non-native trees and shrubs found in central Ohio,
3) Testing of the adapted index in three central Ohio watersheds: the Big Darby, Little Darby, and Walnut Creeks,
4) Assessment of the usefulness of the adapted index in watershed management and planning.

Study Area

Three central Ohio watersheds were used to test the adaptation of the QBR index. These were the Big Darby Creek (Figure 1), the Little Darby Creek (Figure 1), and the Walnut Creek (Figure 2) watersheds. The Big Darby and the Little Darby are both State and National Scenic Rivers, with exceptional water quality in large portions of the watersheds. Walnut Creek is also a stream of high water quality. All three watersheds provide habitat to a wide range of fish, macroinvertebrates, mussels, amphibians, mammals, birds, and other species. Land ownership along these streams is a mix of private and public, with the Columbus Metro Parks being one of the public landowners.

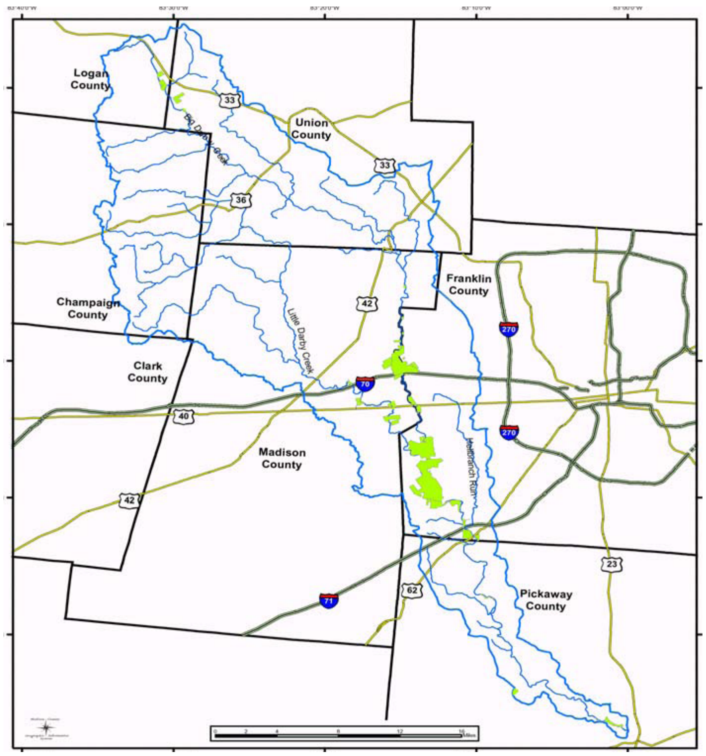

Figure 1: The Big and Little Darby watersheds, located in central Ohio (www.epa.state.oh.us/dsw/documents/BigDarbyTSD2004_A_2_Study%20Area.pdf). The outer line indicates watershed boundary for both the Big and Little Darby Creeks.

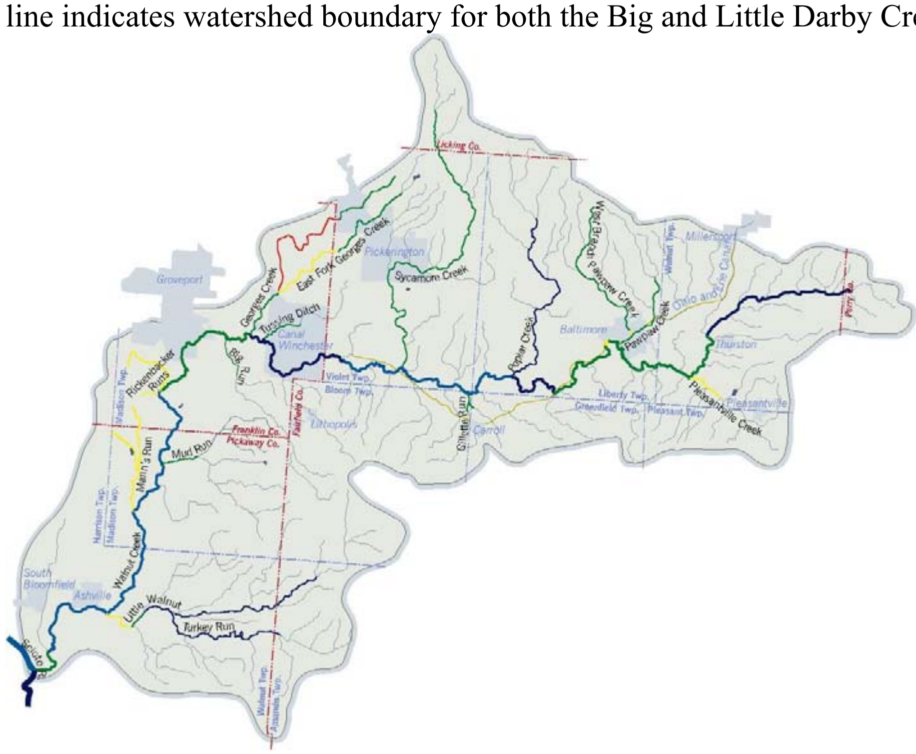

Figure 2: Map of the Walnut Creek watershed (www.epa.state.oh.us/).

Twenty sites were chosen along each of these three streams (Table 1). Recent political and environmental activities along the Darby Creeks have resulted in limited access to the creeks, therefore only limited portions of the watersheds could be sampled. Sampling in the Walnut Creek watershed was conducted with less restrictions, as the work was conducted in conjunction with the stream quality monitoring by the Ohio Environmental Protection Agency (OEPA). Study sites are chosen for their studies based on the amount of land area that is drained at points along the length of the main stream and its tributaries.

Methods

The QBR index developed by Munné *et al*. (2003) (Appendix 1) was created for assessing the riparian forests of Mediterranean area streams. Several changes, therefore, were needed to make it applicable to the riparian forests of central Ohio streams. All of the components of the index were evaluated to determine whether the scoring requirements were adequate as they were originally developed, or if they needed to be altered to more accurately reflect the quality of the riparian forests in central Ohio based on a search of the literature. If any part of the index was found to need revision, another literature review was then conducted to determine how the section could be modified to more accurately reflect the local conditions and relationships.

In addition to altering the index itself, a list of potential native and non-native tree and shrub species was developed (Appendix 2). An initial list was created by reviewing field guides and publications concerning the study areas, and throughout the sampling period new species were discovered. Non-native species are not indigenous to the state, and some have become invasive.

Table 1: Site list for the testing of the adapted QBR index. Stream name and location of each site are given. ust = upstream, dst = downstream, and adj = adjacent.

Big Darby Creek Watershed		Little Darby Creek Watershed		Walnut Creek Watershed	
Stream Name	Site Location	Stream Name	Site Location	Stream Name	Site Location
B. Darby	Dst. of Beech Rd.	L. Darby	Near mouth site 1	UT to UT to Slate Run	Adj. to path
B. Darby	North Coneflower Trail dst. site	L. Darby	Near mouth site 2	Slate Run	Perrill Rd.
B. Darby	North Coneflower Trail ust. Site	L. Darby	Near mouth site 3	E. Br. George Cr.	Ust. Wright Rd.
B. Darby	Quarry Area adj. to tip of southern lake	L. Darby	Near mouth site 4	Big Run	Ust. Elder Run
B. Darby	Quarry Area ust. Southern lake	L. Darby	Adj. Taylor-Blair Rd.	UT to Walnut Cr. @ RM 29.9	Dst. Jefferson Rd.
B. Darby	Quarry Area south of southern lake	L. Darby	Ust. US 42	W. Br. Pawpaw Creek	Dst. Roley Rd.
B. Darby	Quarry Area south of lakes ust. Site	L. Darby	Ust. (1/2 mile) US Route 42	Walnut Cr.	Adj. Walnut Cr. Pike, ust. St. Paul Rd.
B. Darby	Quarry Area south of lakes dst. site	L. Darby	Ust. (1 mile) US Route 42	Walnut Cr.	Ust. Walnut Cr. Pike
B. Darby	Sycamore Plains ust. Site	L. Darby	Ust. Axe Handle Rd.	Walnut Cr.	Adj. Pontius Rd.
B. Darby	Sycamore Plains middle site	L. Darby	Dst. Axe Handle Rd.	Walnut Cr.	Dst. Hayes Rd.
B. Darby	Sycamore Plains dst. site	Treacle	Ust. Winget Rd.	Walnut Cr.	Ust. Gender Rd.
B. Darby	Ust. SR 161 in Plain City Park	Treacle	Dst. Winget Rd.	Walnut Cr.	Dst. Ashbrook Rd. Covered Bridge
B. Darby	Ust. Road crossing in Milford Center	Treacle	Adj. Rte. 4	Walnut Cr.	Ust. Bader Rd.
B. Darby	Dst. road crossing in Milford Center	Treacle	Dst. Eagle Rd.	Walnut Cr.	Ust. Basil Rd.
Spain	Dst. Inskeep Cratty Rd. downstream site	Treacle	Ust. Eagle Rd.	Walnut Cr.	Dst. SR 37
Spain	Dst. Inskeep Cratty Rd. upstream site	UT to L. Darby	Maple Grove Cemetery	Walnut Cr.	Dst. Cromley Rd.
B. Darby	Ust. SR 245	L. Darby	Ust. Rte. 4	L. Walnut Cr.	Adj. South Bloomfield-Royalton Rd.
B. Darby	Dst. (3/4 mile) North Lewisburg Rd.	L. Darby	Ust. Irwin Rd.	E. Br. George Cr.	Dst. Refugee Rd.
B. Darby	Dst. (1/2 mile) North Lewisburg Rd.	L. Darby	Ust. Rosedale-Plain City Rd.	L. Walnut Cr.	Ust. Plazier Rd.
B. Darby	Dst. North Lewisburg Rd.	L. Darby	Dst. Rosedale-Plain City Rd.	L. Walnut Cr.	Dst. Winchester Rd.

Once the index was altered (Appendix 3), it was then tested in the three separate watersheds to determine whether or not the modifications accurately reflected the quality of central Ohio riparian forests. These watersheds were the Big Darby Creek, Little Darby Creek, and Walnut Creek. Within each of these watersheds, 20 study sites were chosen, resulting in a total sample of 60 sites. Sample sites in the Walnut Creek watershed were chosen from the study plan created by the Ohio Environmental Protection Agency (OEPA) for their stream quality monitoring, and were sampled during the summer of 2005 water quality testing. Sites within the Big and Little Darby watersheds were chosen based on accessibility of the creek and adjacent forests.

Each study site was centered on the streambed, and was 50 meters in length following the stream channel. The width was variable, extending through the riparian forest to the edge of the floodplain. Floodplain width was based on the bank topography, position of terraces or dikes, presence of piles of debris left by previous flooding, and also through plant indicator species. In areas with a narrow riparian forest corridor, the forest edge itself was taken to be the edge of the floodplain for the purposes of this study.

After each site location was chosen, the 50-meter length was measured upstream and the edge of the floodplain was marked out, the QBR index was completed. This work was done in four parts following the four sections of the field sheet. Each part, therefore, was assessed separately, and then all were combined at the end for scoring purposes. All field work was conducted during the summer of 2005, after the leaf flush of the trees was finished and before the leaves starting falling. Cover conditions, therefore, were relatively similar for all measurement periods.

The first section of the index to be completed was the total vegetation cover. This section was conducted in several steps, beginning with an estimated measurement of the percent riparian cover present. Riparian cover included the combined percentage of the cover from trees, shrubs, and perennial herbaceous plants, but not that of annual plants, due to the fluctuation in cover annual plants provide through seasonal and environmental changes in density and number. The score given to this part of the section was the highest if percent cover was above 80%; below 80% yielded a lower score depending on how much lower the percent cover was. A score of zero was applied if the cover fell below 10%.

The second part of the first section of the index was a measure of the connectivity of the riparian floodplain forest to any adjoining woodlots. The score obtained in this part can either be negative or positive, and is added or removed from the base score obtained in the first part of the section. If the floodplain forest was connected with another woodlot for over 50% of its edge, five or ten points were added to the base score. If the connectivity was 50% or less, five or ten points were removed from the base score.

The second section of the index deals with the cover structure. The first part of this section gave the base score and was an estimated percent of tree cover. If this measurement was above 75%, it received a perfect score, but received progressively less points as the percentage dropped. A score of zero was applied if the percent cover fell below 10%. Sites with tree cover of 75% or less could include the percent shrub cover to obtain a higher score in this part of the index.

The second part of this section was an estimated measurement of the helophyte (plants whose buds commonly lie in the mud during unfavorable seasons and therefore mainly or exclusively grow in soil or mud that is saturated with water (Helms 1998)) and shrub cover along the edge of the stream itself. Five or ten points were added to the base score if this percentage was 25% or higher. If the percentage of helophytes and shrubs was below 25%, no points were added or removed from the base score. Five points could also be added to this section's base score if the trees and shrubs were interspersed with each other. Finally in this section, five or ten points were deducted from the base score if the trees and shrubs were regularly spaced, or five points were removed if they were in separate patches as opposed to being interspersed.

Section three of the index is based on the cover quality. In order for this section to be completed, the stream type was determined prior to measurements. A separate section on the field sheet was used for this step at each site. To determine the stream type, the shape and slope of the margins of the floodplain were observed and measured. The banks were assessed by determining whether the shape of each bank was convex, concave, or linear, and the slope was measured by taking three measurements with a clinometer at the start of the 50 meter length, at 25 meters, and at the end of the 50 meter length. These three measurements were then averaged to get one measurement for each side. Following these measurements on both banks of the stream, the presence and width of any islands was noted. Any island(s) in the 50 meter length was noted and the width of the island(s) was measured as being less than five meters, or greater than or equal to five meters. Also, the percentage of hard substrata, such as rocks, that would make establishment and growth of vegetation difficult was measured. Each of these measurements received a score, and all of the individual scores were added to get the stream type of 1, 2, or 3 (Table 2).

Table 2: The stream types (and descriptions of general characteristics) used in determining the scoring requirements for the third section of the QBR index.

	Type 1	Type 2	Type 3
Characteristics	Closed riparian habitats Riparian trees, if present, reduced to small strip Headwaters First order streams	Headwaters or midland riparian habitats Forest may be large and originally in a gallery First or second order streams	Large riparian habitats Potentially extensive forests Third or higher order streams

Once the stream type was determined, the third section of the index could be completed. The base score for this section was found by counting the number of native tree species that were established in the sample zone. Established trees were taken to be any woody plant that was self-supporting and taller than four and a half feet. These species were recorded in the provided space on the field sheet to ensure that species were not missed or double counted. Non-native species were also recorded, but were not included in the total number of species for the scoring. The score received was dependent on the stream type and the number of species found (Table 3).

Table 3: Number of native tree species required by stream type and scoring requirements.

Stream Type	# of species for 5 points	# of species for 10 points	# of species for 25 points	# of shrubs
1	>2	>4	>6	>3
2	2	4	6	>4
3	1	3	5	>5

Next, the continuity of the tree cover along the stream itself was measured by looking for gaps and determining the amount of stream edge that was shaded by the tree cover. If this measurement was at least 50% cover, five or ten points were then added to the base score for the section. Five points were also added when the number of shrub species was above the threshold limit for the stream type (Table 3). Five points were then deducted for any buildings in the floodplain, and ten points were deducted for the presence of garbage (such as from dumping), which was determined by the amount. If there were large amounts of garbage that were not the result of flooding, the points were subtracted. The points were not deducted for this part if the garbage was limited and/or the result of natural flooding. In this section, five points were removed from the base score for the presence of isolated non-native tree and shrub species as well. Ten points were removed if the non-native trees or shrubs were in communities as opposed to being scattered or isolated.

Finally, section four of the index dealt with any channel alterations that were present along or in the stream. Unmodified channels received the highest score possible for this section. The base score is determined by the stream channel itself, whether it is unmodified, has had terraces modified, had rigid structures along the margins to constrain the channel, or has been channelized. Any site where the stream was channelized received a zero for this section. No additional points could be added, but points were removed from the base score if there were rigid structures in the river bed or if there were weirs or fords that crossed the channel.

When all four sections were completed, the score for each was calculated by taking the base score and then adding or subtracting the additional points that were scored in that section. No individual section score, however, could fall below zero or exceed 25, thus, each of the sections held equal weight in the final score. All four of these scores were then totaled to give the total site score ranging from 0 to 100 (Table 4).

Table 4: Scoring process for the QBR index.

	Lowest Possible Score	Highest Possible Score	Score Derived From
QBR Index	0	100	Sum of Sections 1-4
Section 1	0	25	Sum of Components of Section 1
Section 2	0	25	Sum of Components of Section 2
Section 3	0	25	Sum of Components of Section 3
Section 4	0	25	Sum of Components of Section 4

Following the completion of the field work, to assess the changes made to the original QBR index, the values for each category and scores for each site were analyzed to determine the effectiveness of the altered index. The data collected at all of the study sites for this project was then assessed using the original QBR index, and these results were then compared with the results scored in the field.

A one-way ANOVA was then run comparing the final scores from each of the three watersheds to determine if any statistical difference exists between them. The alpha level was set at 0.05, with a sample size (n) of three.

Results

Alterations to the QBR Index

Several changes to the original QBR index were needed to adapt it to central Ohio riparian forests. Section 1 of the field sheet was the only section to remain the same in the altered index as in the original QBR. All three of the other sections were at least slightly altered to reflect the differences between the floodplains of Spain's Mediterranean streams and those of the streams of central Ohio.

The minor changes made to the second section of the index were needed to clarify the application of the index in the field. For the amount of tree and shrub cover, the numbers in the scoring were changed from 10-25% to 10-24%, since 25% was included in the category above this one. A similar change was made to the part of section two dealing with the helophyte and shrub edge cover. Here, the requirement was changed from 25-50% to 25-49% for the same reasons as the previous alteration. Also in this section, in the component dealing with the distribution of trees and shrubland cover, the second scoring category was changed to shrubland of less than or equal to 50%, since 50% was not included in either option, the first being >50%, and the second being <50%. This also simplified the scoring while sampling.

The third section of the index had the most significant changes among all of the sections. The first change made to this section was to adjust the number of species required for each habitat type and score (Table 5). The number of tree species required was changed from the original numbers presented by Munné *et al*. (2003) to double that number for the adapted index for central Ohio based on the literature review. Also in this section, the number of shrub species was increased to reflect the difference in species richness between Mediterranean Spain and central Ohio.

Table 5: Changes made to the species richness requirements for scoring the third section of the index.

Habitat Type	Index	Number for 5 points	Number for 10 points	Number for 25 points	Number of Shrubs
Type1	Original	>1	>2	>3	>2
	Adapted	>2	>4	>6	>3
Type 2	Original	1	2	3	>3
	Adapted	2	4	6	>4
Type 3	Original	0	1	1 or 2	>4
	Adapted	1	3	5	>5

The next change in section three of the index was to remove the scoring for the riparian area being structured in a gallery; this was not applicable to central Ohio. Finally in section three, the negative scoring for the presence of non-native trees was changed to apply non-native shrubs as well.

In the fourth section of the index, changes were made to the scoring requirements for modifications of the channel. The scores provided by Munné *et al*. (2003) in the original index were kept, but the factors contributing to that score were changed to require that both stream banks be modified to receive these scores. New categories were made to include sample sites with only one bank modified. The first category created was "fluvial terrace on one bank modified and constraining river channel" and has an associated score of 15. The second category created was "channel modified by rigid structures along one margin" and has an associated score of 10.

Minor changes were also made in this section concerning the riparian habitat type and they were similar to the changes made in section two. The width of the islands categories were changed so that the first option included 5 meters, as the original options were >5 meters and <5 meters. The new requirements were changed to be ≥5 meters and <5 meters. The percentage classes for the percentage of hard substrata were also changed to clarify which class each measurement belonged to. The classes were changed from >80%, 60-80%, 30-60%, and 20-30% to >80%, 60-80%, 30-59%, and 20-29%. All scores associated with these percentage classes remained the same.

The final changes made to the index were format changes. The setup of the field sheet was altered and locations to record species and to take notes were added. All of these changes were made to make the field sheet easier both to follow and to complete.

Comparison of the Original and Adapted QBR Indices

Scores from each site were computed for both the original index as created by Munné *et al*. (2003) and for the adapted index. Some differences were found between the scores. Of the 60 sites, two scored higher with the adapted index and four scored lower with the adapted index (Table 6). All other sites received the same score with both indices. Of the six sites with varying scores, only one was placed in a higher habitat quality class when the adapted index was used.

Table 6: Differences in scores with the original index (by Munné *et al*. (2003)) verses the adapted index. ust = upstream and dst = downstream.

Creek	Site	Score with Original Index	Score with Adapted Index	Change Quality Class?
Big Darby Cr.	dst. Beech Rd.	80	85	no
Little Darby Cr.	ust Axe Handle Rd.	45	50	no
Little Darby Cr.	dst Axe Handle Rd.	50	60	yes
UT to Walnut Cr. @ RM 29.9	dst Jefferson Rd.	90	85	no
Walnut Cr.	ust Gender Rd.	65	60	no
Little Walnut Cr.	dst Winchester Rd.	65	70	no

The sections of the index with the most variability in scores between the original and the adapted index were sections three and four. Several sites received higher scores with the adapted index due to the addition of score classes in section four if only one side of the stream channel was altered. One site, however, received a lower score with the adapted index due to the changes in the number of tree and of shrub species. Other sites also received lower scores due to the addition of non-native shrubs to the non-native trees category.

Riparian Forest Habitat Quality in the Study Watersheds

Overall, site scores with the adapted index ranged from 45 to 100 (Figure 3), compared to scores from 50 to 100 with the original index developed by Munné *et al*. (2003). No statistical differences were determined between the habitat qualities within the three watersheds (F=0.94, P=0.397). For both indices, individual section scores ranged from zero to 25, with many of the sections scoring beyond the set limits of zero and 25. These additional and negative points in the sections contributed to various sites' scores, but were not counted due to the requirements of the index to give each section an equal weight in the overall score.

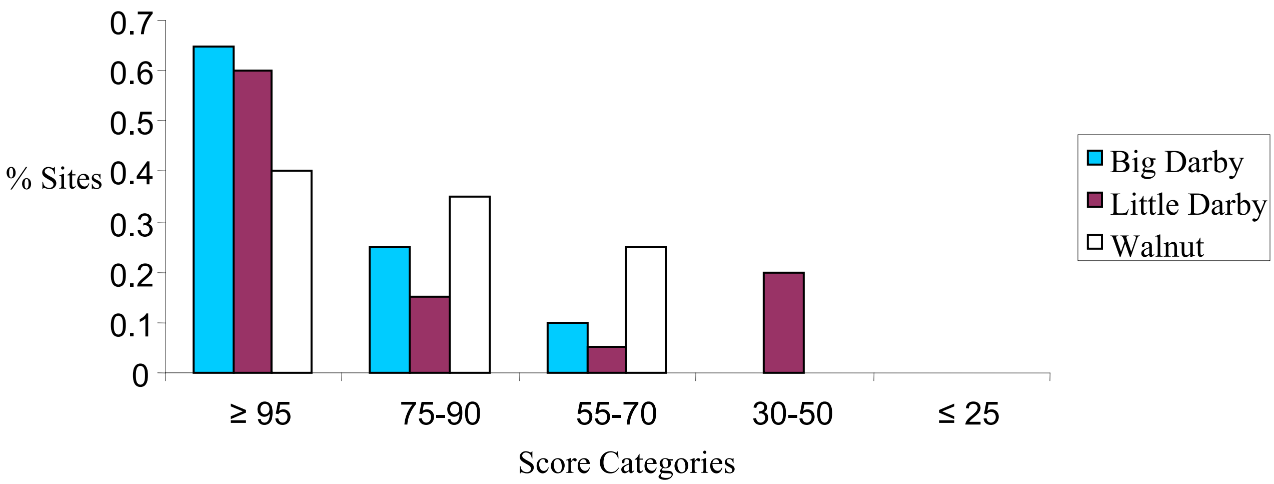

Figure 3: Percentages of sites in each total score category by watershed.

No sites were in the very poor habitat class, and only four sites, all within the Little Darby watershed in highly agricultural areas, were in the poor quality class. Most sites, however, were in the fair, good, or excellent habitat quality classes (Table 7).

Table 7: Descriptions of riparian habitat quality classes determined by the QBR index.

Riparian Habitat Class	QBR Score
Riparian habitat in natural condition, excellent quality	≥95
Some disturbance, good quality	75-90
Disturbance important, fair quality	55-70
Strong alteration, poor quality	30-50
Extreme degradation, very poor quality	≤25

The sample sites studied were of the second or third habitat type (Figure 4), which are characterized by having wider floodplains. In the Big Darby watershed, all of the study sites were in the third habitat class, with the average slopes of the banks ranging from 0-61.5°. Three of the sites had islands greater than five meters across and two sites had islands less than five meters across. None of the sites in this watershed had a high enough percentage of hard substrata to influence the growth of vegetation.

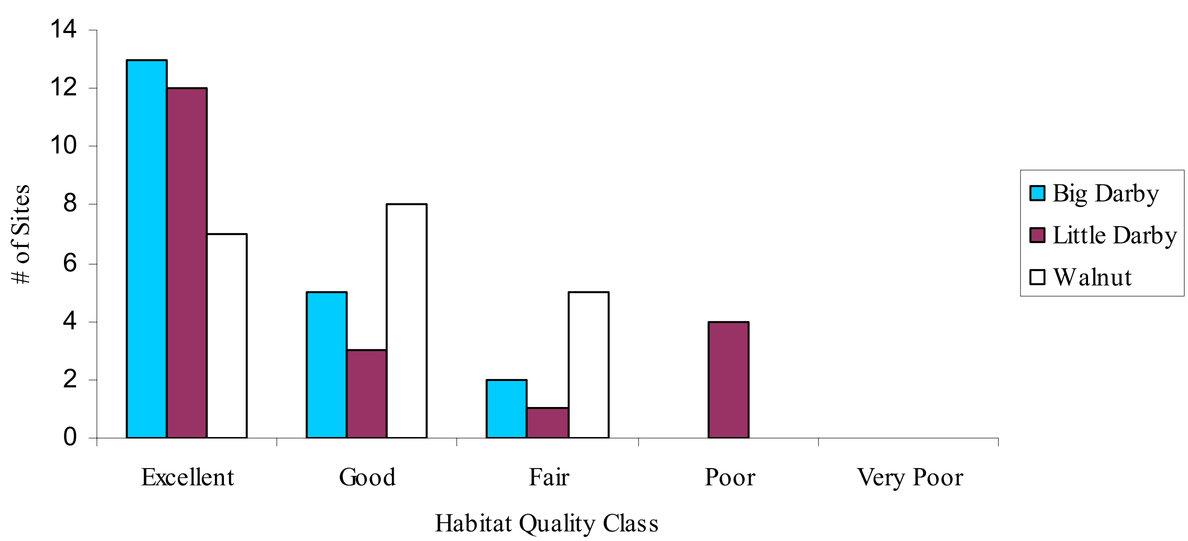

Figure 4: Habitat classes for study sites in the three watersheds.

In the Little Darby Watershed, seven sites were in the second habitat class and the remaining 13 were in the third habitat class. Average bank slopes ranged from 12-67.5°, and two sites had islands greater than five meters across and two had islands less than five meters across. One site in this watershed had 25% hard substrata, which resulted in the deduction of two points from the habitat score.

The Walnut Creek watershed had 14 sites in the second habitat class and six in the third class. Average bank slopes ranged from 12-59°, with one site having islands greater than five meters and two sites with islands less than five meters. Three sites had 25% hard substrata, and one had 20%, all three of which resulted in a two point deduction from their overall habitat scores.

Section one was usually the lowest scoring section of the index. These scores ranged from zero to 25 (Figure 5). The Big Darby Creek watershed had the highest scores with twelve sites attaining scores of 25, three sites attaining 20, four sites attaining 15, and one site attaining five. In the Little Darby watershed, ten sites scored 25, three sites scored 20, two sites scored 15, one scored 10, one scored five, and three scored zero. The Walnut Creek Watershed had the most scores in this section that were lower, with only six sites attaining 25 points. Three sites in this watershed scored 20, five scored 15, three scored five, and three scored zero.

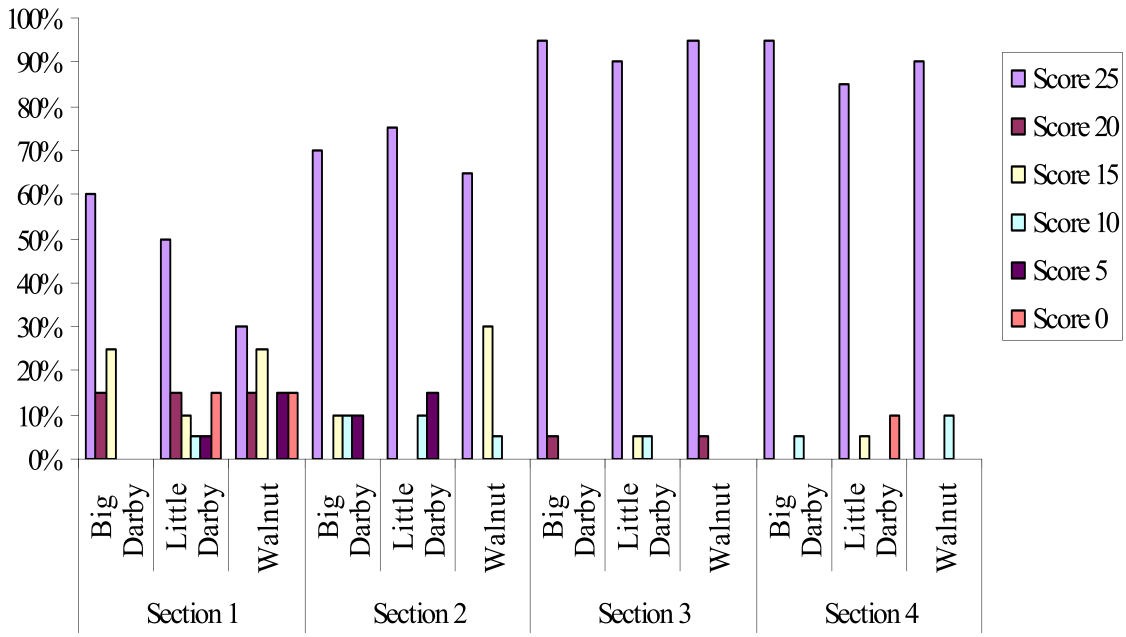

Figure 5: Percentage of sites within each watershed for each section score.

The percent riparian cover in the Big Darby watershed ranged from 60-95% (mean = 82%). The percent connectivity with adjacent woodlands ranged from 50-100% (mean = 71%). In the Little Darby watershed, percent riparian cover ranged from 30-100% (mean = 78%), and connectivity ranged from 0-100% (mean = 59%). Finally, in the Walnut Creek watershed, percent riparian cover ranged from 45-98% (mean = 77%) and the connectivity ranged from 0-100% (mean = 47%) (Figures 6 and 7).

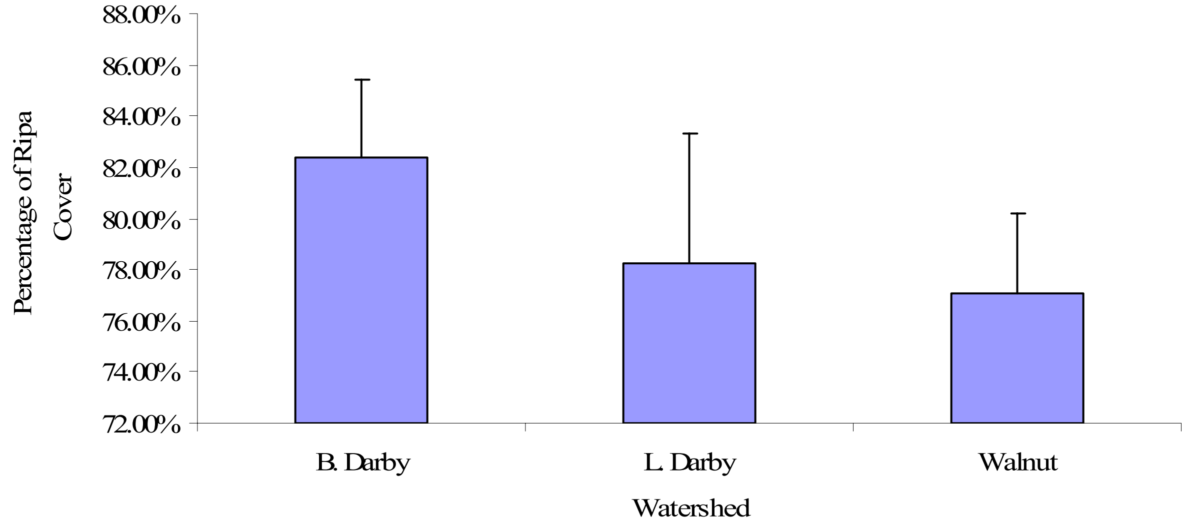

Figure 6: Average percent riparian cover and standard error for each watershed.

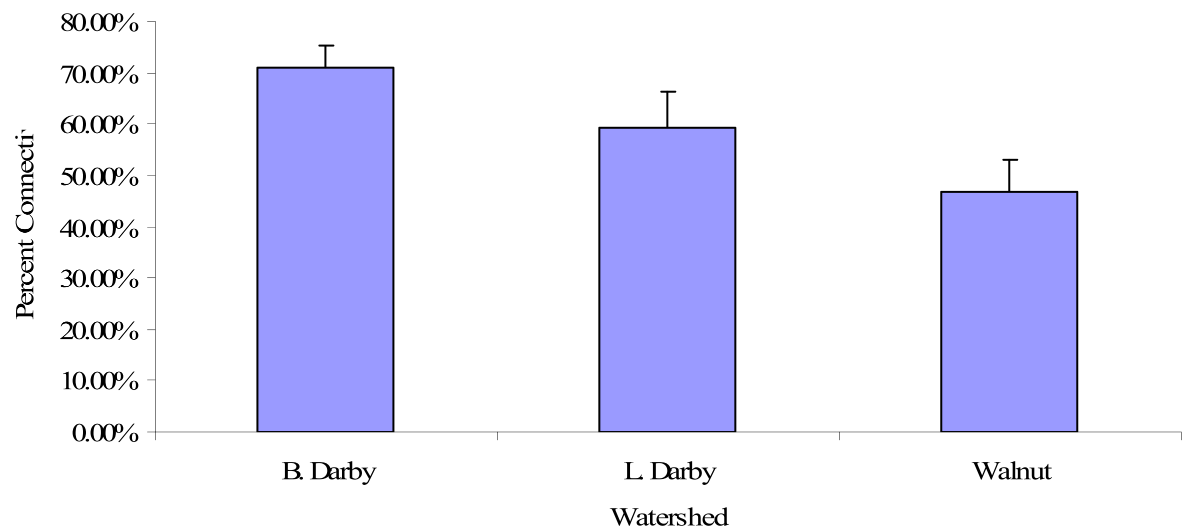

Figure 7: Average percent connectivity and standard error for each watershed.

The scores for section two of the adapted QBR Index were generally higher than those of section one. Scores for this section ranged from 5-25. In the Big Darby Creek watershed, two sites scored five points, two scored 10, two scored 15, and fourteen scored 25. In the Little

Darby Creek Watershed, three sites scored five points, two sites scored 10 points, and fifteen scored 25. In the Walnut Creek Watershed, two sites scored 10 points, five scored 15, and thirteen scored 25 (Figure 5).

In section two, the riparian cover was divided into tree cover and helophyte and shrub edge cover. The Big Darby Creek sites had tree cover of 40-95% (mean = 85%), the Little Darby sites had tree cover of 30-95% (mean = 75%), and the Walnut sites had tree cover of 45-98% (mean = 75%) (Figure 8). Helophytes and shrubs along the riparian edge were not present at all of the sites. Along the Big Darby, only seven sites had helophytes, and the cover ranged from 30-60% (mean = 47%). The Little Darby had eight sites with helophytes and along the riparian edge with percentages of 5-80% (mean = 42%). Walnut Creek only had three sites with helophytes, and their percentages were 5%, 15%, and 75% (Table 8).

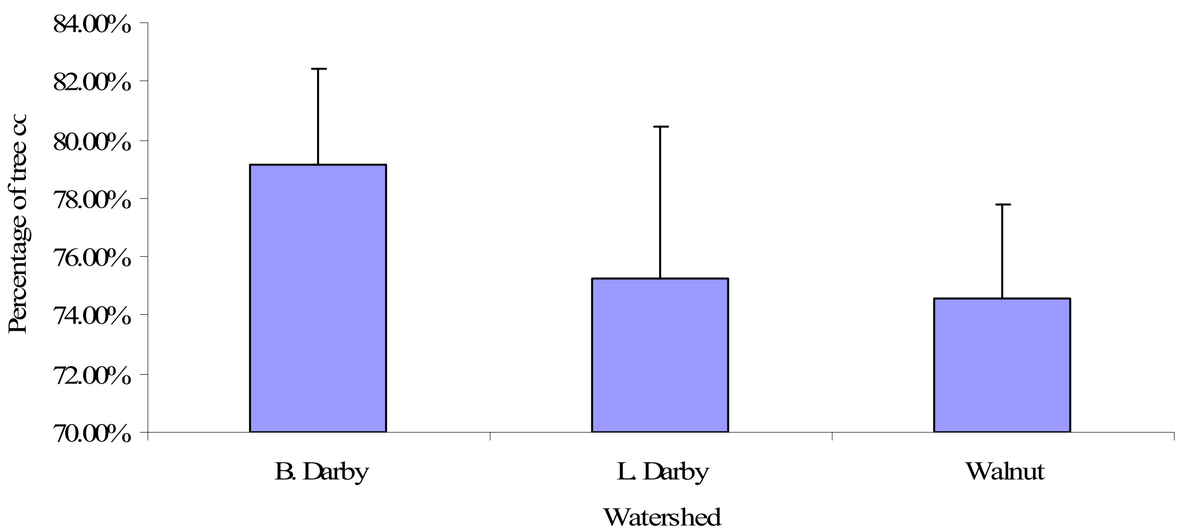

Figure 8: Average percent tree cover and standard error for each watershed.

Table 8: Sites with helophyte cover and the percentage of helophyte cover at each site for all watersheds. ust = upstream, dst = downstream, adj = adjacent, and POMP = Prairie Oaks Metro Park.

Creek	Site	% Helophytes
Big Darby Creek	POMP Quarry Area tip of Southern Lake	55%
Big Darby Creek	POMP Quarry Area tip of Southern Lake ust site	30%
Big Darby Creek	POMP Quarry Area dst Bridge South of Lake	50%
Big Darby Creek	POMP South of Quarry Lake dst site	60%
Big Darby Creek	POMP South of Quarry Lake dst site 2	55%
Big Darby Creek	POMP Sycamore Plains ust site adj to trail	45%
Treacle Creek	dst Eagle Rd.	35%
Little Darby Creek	at mouth site 1	30%
Little Darby Creek	ust mouth site 2	75%
Little Darby Creek	ust mouth site 3	75%
Little Darby Creek	ust mouth site 4	80%
Little Darby Creek	adj. Taylor-Blair Rd.	50%
Little Darby Creek	ust US 42	10%
UT to Little Darby Creek	Maple Grove Cemetery	5%
Little Darby Creek	ust Rte. 4	10%
Walnut Creek	adj. Pontius Rd.	10%

One site within the Big Darby Creek watershed had a regular spatial pattern of the trees, as it was located within a city park where the trees had been planted. This distribution, along with a low amount of shrub cover, lowered the score in this section for the site by 10 points.

The third section of the index had the highest scores for all three watersheds. Sites in the Big Darby watershed all had scores of 25 except one, which scored 20. In the Little Darby watershed, all but two sites scored 25, with one score of 10 and one of 15. All but one site (score of 20) scored 25 in the Walnut Creek watershed (Figure 5).

The baseline score for section three was based on the native tree species richness. Richness was generally relatively high in all three watersheds. In the Big Darby watershed, the highest number of tree species encountered at a site was 16 species, and the lowest was nine species (mean = 12.4). The Little Darby watershed had 13 species at the site with the highest species richness, and five species was the lowest species richness (mean = 8.75). In the Walnut

Creek watershed the site with the highest species richness had 17 species, and the lowest had eight species (mean = 11.4) (Figure 9). Shrub species richness in the Big Darby ranged from zero to six, in the Little Darby from zero to five, and in the Walnut from zero to eight (Figure 10).

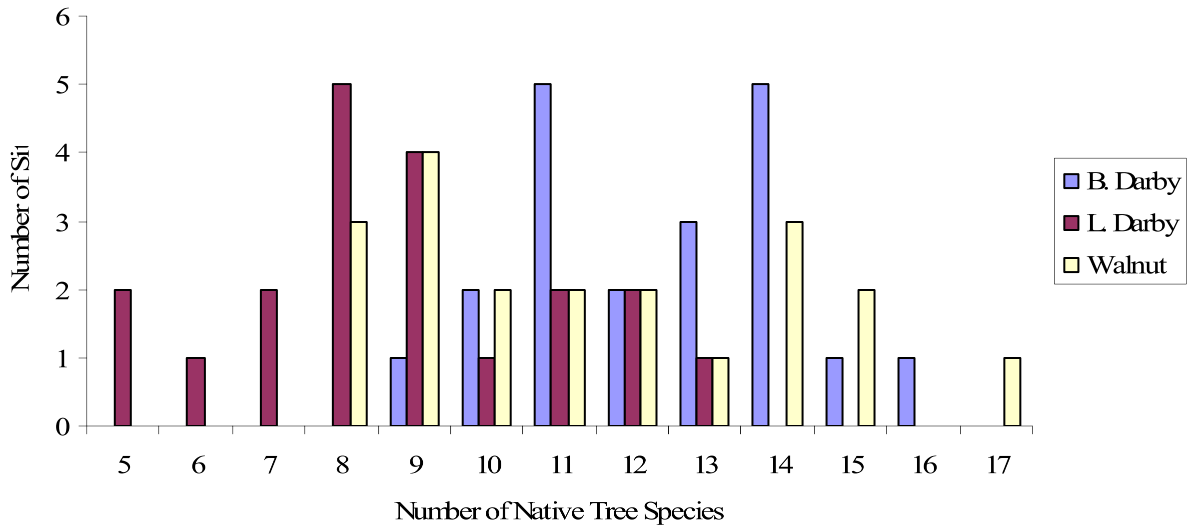

Figure 9: Tree species richness for sites in the three study watersheds.

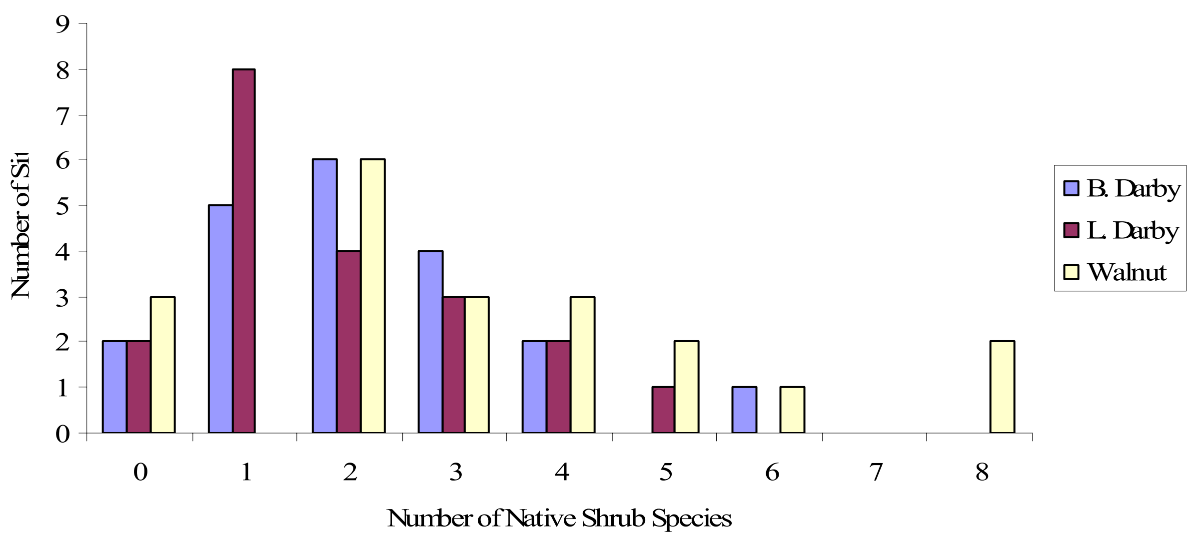

Figure 10: Shrub species richness for sites in the three study watersheds.

Two sites, one in the Big Darby watershed and one in the Little Darby watershed, had buildings located within the riparian area, resulting in a loss of five points from the base score of section three. Two different sites, one in the Little Darby watershed and one in the Walnut watershed, had large quantities of garbage that was restricting regeneration in small areas, resulting in a loss of 10 points at each.

Isolated non-native tree and shrub species were found in 11 Big Darby watershed sites, 14 Little Darby watershed sites, and 12 Walnut Creek watershed sites. Communities of non-native tree and shrub species were found at four Big Darby sites, at one Little Darby site, and at three Walnut sites. One of the Big Darby sites had both present. Non-native species found in these sites were primarily bush honeysuckle (*Lonicera maackii*) and multiflora rose (*Rosa multiflora*), however, other species were also found (Table 9).

Table 9: Presence of isolated and communities of non-native tree and shrubs within the study watersheds.

	Number of Sites Present in					
	Big Darby		Little Darby		Walnut	
Species	Isolated	Communities	Isolated	Communities	Isolated	Communities
Eleaegnus umbullata	0	0	2	0	0	0
Ligustrum vulgare	2	0	3	0	2	0
Lonicera maackii	7	4	10	1	10	3
Rosa multiflora	3	2	6	0	6	1
Salix babylonica	2	0	4	0	1	0

The Big Darby watershed sites scored the highest of the three watersheds on section four of the index. All sites scored 25 except for one, which scored 15. The Little Darby watershed had 22 sites score 25, one score 15, and the remaining two scored zero points. The Walnut Creek watershed had all but two sites score 25, with the two that did not both receiving a score of 15 (Figure 5).

In all of the watersheds, any site that was a stream channel with no modifications or channelization scored 25 points. These were sites where the stream channel was in a natural geomorphologic condition. The Big Darby site that scored 15 had one of the stream banks diked, the two Little Darby sites that scored zero were both channelized, while the site that scored 15 had a man-made structure located within the floodplain. The Walnut Creek sites that received scores of 15 both had terraces modified.

Discussion

Alterations to the QBR Index

The changes made to the original QBR index did not result in major changes to the scores of the sites utilized in this study. The changes, however, resulted in a better reflection of the habitat quality when the individual components were assessed. The number of native species required in the third section of the index was increased to reflect the differences between the native tree and shrub diversity in Spain and that of the United States. Even with this increase in the number required, only one site had less than the number of tree species needed for the maximum points for the score of that section. The increase in the number of shrub species appears to be a needed increase since eleven of the total sites had the minimum number of species required for the extra points to section three's scores. More sites had enough total shrub species to score the additional points, but some of the species were non-native and therefore were not included in the total numbers here.

The other changes also appear to be supported by the data collected in the field testing. No sites were found to be structured in a gallery, so the removal of this portion of the index did not affect the overall scores of the index. The change in scoring from having both stream banks modified to having one or both modified reflected more accurately the available habitat and establishment area for trees and shrubs when only one bank is modified as opposed to those sites with both banks modified.

Changing the category of non-native trees to non-native trees and shrubs was needed since only one non-native tree species was recorded in the study areas but four non-native shrub species were found, as opposed to no native shrub species in the study by Munné *et al.* (2003). This component of the index is important especially in central Ohio where bush honeysuckle is present in many human-disturbed ecosystems. Most riparian forests in central Ohio are disturbed in at least some way, but most have been drastically disturbed (Corbacho *et al*. 2003). The most profound example of this is in agricultural settings where the riparian forests may be only a thin remaining strip of trees, or in extreme cases, where all of the woody vegetation is removed from these areas.

All of the changes made to the index were supported by the field testing. The adapted index is a more accurate reflection of the habitat quality in central Ohio riparian forests than the original index. The QBR index, as developed by Munné *et al.* (2003), provided the basic guidelines for the determination of a habitat quality for sections of riparian forest under study.

Riparian Forest Habitat Quality in the Study Watersheds

Although the results of the one-way ANOVA indicated no statistical differences between the riparian forest habitat qualities of the three study watersheds, the Big Darby Creek watershed had the most sites in the excellent habitat quality class, which was supported by several determinations of the index. It had the highest average percent cover of 82%, the highest average connectivity of 71%, and the highest average number of native tree species at each site of 12.4 species. The Little Darby Creek and the Walnut Creek watershed had lower numbers of sites in the excellent habitat quality class. These trends were anticipated at the beginning of the study, since the Darby Watersheds are national and state Scenic Rivers, and are known for their high water quality. In many areas, the riparian forest has been preserved and has been left intact along the stream banks. It was not expected, however, that among the three watersheds there would be no statistically significant differences.

Management Implications

The QBR index provides a basic habitat quality value for a sample site. The results obtained from the testing of the index could be utilized in several ways. Most of the study sites in the study watersheds scored relatively high. These streams, therefore, may be areas where conservation efforts should be directed and in several cases, already have been directed. Those sites that did not score in the excellent habitat quality class would be areas where the conservation efforts could be directed within these watersheds to improve the habitat over the whole watershed.

This index also allows watershed managers to determine what factors of the riparian forest are the most limiting in terms of habitat. Most sites sampled that obtained less than excellent scores received lower scores due to reduced riparian and tree cover and reduced connectivity with adjacent woodlots. Improving the habitat quality by increasing cover requires planning, funding, and time. Plantings could increase cover in some of these areas, but it would take years to increase the tree cover. Given time and good management planning, however, the riparian forest habitat quality would be increased.

In other watersheds, this index could be used in restoration projects to follow the succession of the forests as they mature. By using this index every five to 10 years, the changes in these areas could be determined and documented. The limiting components of the forests would also be assessed, and as needed, changes could be made to the management plans for the area to account for and improve any deficiencies in the riparian areas.

Conclusions

The QBR index is needed in central Ohio for several reasons. There currently is no method for assessing the habitat quality of riparian forests. While the QBR index provides a general habitat quality class to the section of the stream, it provides a baseline value for the habitat quality of the area. Further studies can be completed to examine the ecosystem components of the riparian forest of interest.

Riparian forests are some of the most diverse habitat types in Ohio, with high species richness and many important functions in ecosystem processes (Innis *et al.* 2000). They are also some of the most endangered ecosystems in the world today. The QBR index is a method for assessing the habitat quality of riparian forests. This index can be used to assess the current quality of riparian forests, and it can also be used to follow the progress of restoration projects in riparian areas. It could also be used to determine areas in a watershed that need the most attention, when determining where to allocate funds for improving the riparian forests and water quality.

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Appendix 1

Original QBR Index

APPENDIX: *FIELD SHEET*

QBR INDEX

Riparian habitat quality

Score of each part cannot be negative or exceed 25

Station	
Date	

Section 1: Total riparian cover Section 1 Score

Score		
25	>80% of riparian cover (excluding annual plants)	
10	50–80% of riparian cover	
5	10–50% of riparian cover	
0	<10% of riparian cover	
+ 10 + 5	If connectivity between the riparian forest and the woodland is total If the connectivity is higher than 50%	
– 5 – 10	Connectivity between 25% and 50% Connectivity lower than 25%	

Section 2: Cover structure Section 2 Score

Score		
25	>75% of tree cover	
10	50–75% of tree cover or 25–50% tree cover but 25% covered by shrubs	
5	Tree cover lower than 50% but shrub cover at least between 10% and 25%	
0	<10% of either tree or shrub cover	
+ 10 + 5 + 5	At least 50% of the channel has helophytes or shrubs If 25–50% of the channel has helophytes or shrubs If trees and shrubs are in the same patches	
– 5 – 5 – 10	If trees are regularly distributed and shrubland is >50% If trees and shrubs are distributed in separate patches, without continuity Trees distributed regularly, and shrubland <50%	

Section 3: Cover quality *(the geomorphological type should be first determined[a])* Section 3 Score

Score		***Type 1***	***Type 2***	***Type 3***	
25	Number of native tree species	>1	>2	>3	
10	Number of native tree species	1	2	3	
5	Number of native tree species	0	1	1 – 2	
0	Absence of native trees	-			
+ 10 + 5 + 5 + 5	If the tree community is continuous along the river and covers at least 75% of the edge riparian area The tree community is nearly continuous and covers at least 50% of the riparian area If the riparian community is structured in gallery When the number of shrub species is	>2	>3	>4	
– 5 – 5 – 10 – 10	If there are some man-made buildings in the riparian area If there are some isolated species of non-native[b] trees Presence of communities of non-native[b] trees Presence of garbage				

Section 4: Channel alteration Section 4 score

Score		
25	Unmodified river channel	
10	Fluvial terraces modified and constraining the river channel	
5	Channel modified by rigid structures along the margins	
0	Channelized river	
– 10 – 10	River bed with rigid structures (e.g., wells) Transverse structures into the channel (e.g., weirs)	

Final score (sum of four section scores)	

[a] **Type of the riparian habitat (to be applied at level 3, cover quality)**
The score is obtained by addition of the scores assigned to left and right river margins according to their slope. This value can be modified if islands or hard substrata are present.

		Score	
Slope and form of the riparian zone		Left	Right
Very steep, vertical or even concave (slope >75°), very high, margins are not expected to be exceeded by floods. *Slope is the angle subtended by the line between the top of the riparian area and the edge of the ordinary flooding of the river.*		6	6
Similar to previous category but with a bankfull which differentiates the ordinary flooding zone from the main channel.		5	5
Slope of the margins between 45° and 75°, with or without steps. (*a>b*)		3	3
Slope between 20° and 45°, with or , with or without steps. (a < b)		2	2
Slope <20°, large riparian zone.		1	1
Presence of one or several islands in the river			
Width of all the islands "a" > 5 m.		- 2	
Width of all islands 'a' < 5 m.		- 1	
Percentage of hard substrata that can make impossible the presence of plants with roots			
> 80%		Not applicable	
60 – 80%		+ 6	
30 – 60%		+ 4	
20 – 30%		+ 2	
Total Score			

Geomorphological type according to the total score

>8	**Type 1**	Closed riparian habitats. Riparian trees, if present, reduced to a small strip. Headwaters.
5 – 8	**Type 2**	Headwaters or midland riparian habitats. Forest may be large and originally in gallery.
<5	**Type 3**	Large riparian habitats, and potentially extensive forests. Lower courses.

[b] **Non-native tree species in the study area**
(This should be listed for each study area)

e. g. in the studied area of Catalonia the following species are considered non-native: *Populus deltoides, Populus* x *canadensis, Populus nigra* ssp. *italica, Salix babilonica, Ailanthus altissima, Celtis australis, Robinia pseudo-acacia, Platanus* x *hispanica.*

Appendix 2

Species Lists

Tree species recorded during field work and the number of sites within each watershed each species was present. Asterisk indicates non-native.

Tree Species	Big Darby Creek	Little Darby Creek	Walnut Creek
Acer negundo	20	17	18
Acer rubrum	1	1	2
Acer saccharinum	9	8	9
Acer saccharum	11	7	12
Aesculus glabra	17	3	13
Betula nigra	1	0	1
Betula papyrifera	0	0	1
Carpinus caroliniana	3	0	3
Carya cordiformis	1	1	4
Carya ovata	1	0	0
Catalpa spp.	3	1	2
Celtis occidentalis	18	7	19
Crataegus spp.	6	8	0
Fagus grandifolia	0	0	3
Fraxinus americana	1	1	1
Fraxinus pennsylvanica	17	15	19
Fraxinus quadrangulata	0	0	1
Gleditsia triacanthos	13	13	7
Juglans nigra	17	12	17
Liriodendron tulipifera	0	0	1
Maclura pomifera	10	7	9
Morus spp.	10	12	8
Ostrya virginiana	5	0	1
Platanus occidentalis	13	14	18
Populus deltoides	9	14	10
Prunus serotina	0	0	6
Quercus alba	0	0	1
Quercus imbricaria	0	0	1
Quercus macrocarpa	3	1	0
Quercus muehlenbergii	6	0	2
Quercus palustris	0	0	1
Quercus rubra	0	1	3
Robinia pseudo-acacia	1	0	1
*Salix babylonica**	2	4	1
Salix nigra	14	13	8
Sassafras albidum	1	0	0
Tilia americana	6	3	6
Tsuga canadensis	0	0	2
Ulmus americana	18	9	13
Ulmus rubra	12	6	4

Shrub species recorded during field work and the number of sites within each watershed each species was present. Asterisk indicates non-native.

Shrub Species	Big Darby Creek	Little Darby Creek	Walnut Creek
Aesculus glabra	2	0	0
Asimina triloba	4	0	11
Cercis canadensis	2	3	3
Cornus alternifolia	0	0	1
Crataegus spp.	4	0	1
*Elaeagnus umbellata**	0	2	0
Euonymus atropurpureus	0	0	2
Ilex verticillata	0	0	2
*Ligustrum vulgare**	2	3	2
Lindera benzoin	2	4	5
*Lonicera maackii**	11	11	13
Morus spp.	1	2	0
Rhus glabra	2	1	0
*Rosa multiflora**	5	6	7
Rubus allegheniensis	1	1	3
Rubus occidentalis	0	0	1
Salix amygdaloides	1	0	0
Salix interior	3	11	2
Salix lucida	0	1	0
Salix rigida	0	1	0
Salix spp.	1	0	3
Sambucus canadensis	0	2	3
Smilax spp.	2	0	3
Staphylea trifolia	6	4	6
Toxicodendron radicans	9	5	16
Viburnum acerifolium	0	2	1
Viburnum prunifolium	2	1	4

Helophyte species recorded during field work and the number of sites within each watershed each species was present. Asterisk indicates non-native.

Helophyte Species	Big Darby Creek	Little Darby Creek	Walnut Creek
Sagittaria latifolia	2	0	0
Typha spp.	0	1	0
Equisetum spp.	0	1	2
Saururus cernuus	6	2	0
Justicia americana	1	2	0

Appendix 3

The Adapted QBR Index

QBR Index: Riparian Forest Habitat Quality Field Sheet

Location: ____ RM: ___________ Date: ____________

Observer(s): ____ Time Sampled: _________________________

Score of each section cannot be negative or exceed 25 points

Section 1: Total Riparian Cover

Score	*Riparian Cover Includes Trees, Shrubs, and Helophytes, but not Annuals*
25	>80% of riparian cover (excluding annual plants)
10	50 – 80% of riparian cover
5	10 – 50% of riparian cover
0	<10% of riparian cover
+10 +5	If connectivity between the riparian forest and adjoining woodland is total If the connectivity is higher than 50%
-5 -10	If the connectivity is between 25 – 50% If the connectivity is <25%
	Total Score for Section 1

Section 2: Cover Structure

25	>75% of tree cover
10	50 – 75% of tree cover or 25 – 50% of tree cover but 25% covered by shrubs
5	Tree cover <50% but shrub cover between 10 – 24%
0	<10% of either tree or shrub cover
+10 +5 +5	At least 50% of cannel has helophytes or shrubs If 25 – 49% of channel has helophytes or shrubs If trees and shrubs are in the same patches
-5 -5 -10	If trees are regularly distributed, and shrubland is >50% If trees and shrubs are in separate patches, without continuity Trees are distributed regularly, and shrubland is ≤50%
	Total Score for Section 2

Section 3: Cover Quality (based on geomorphological type)

		Type 1	Type 2	Type 3
25	Number of native tree species	>2	>4	>6
10	Number of native tree species	2	4	6
5	Number of native tree species	1	≤3	≤5
0	Absence of native tree species			
+10 +5 +5	If tree community is continuous along the river and covers at least 75%of the edge riparian area Tree community is nearly continuous and covers at least 50% of the riparian area When the number of shrub species is	>3	>4	>5
-5 -5 -10 -10	If there are some man-made buildings in the riparian area If there are some isolated species of non-native trees Presence of communities of non-native trees Presence of garbage			
	Total Score for Section 3			

Section 4: Channel Alteration

25	Unmodified river channel
15 10	One fluvial terrace modified and constraining river channel Both fluvial terraces modified and constraining river channel
10 5	Channel modified by rigid structures along one margin Channel modified by rigid structures along both margins
0	Channelized river
-10 -10	River bed with rigid structures (e.g. wells) Transverse structures into the channel (e.g. weirs or river crossings)
	Total Score for Section 4

	Final QBR Index Score (Sum of all four sections)

Type of the Riparian Habitat (for Section 3, Cover Quality)
The score is obtained by addition of the scores assigned to the left and right river margins according to their slope. Slope is the angle subtended by the line between the top of the riparian area and the edge of the ordinary flooding of the river.

	Score	
Slope and form of the riparian zone	**Left**	**Right**
Very steep, vertical or even concave (slope >75◦), very high, margins not expected to be exceeded by floods	6	6
Similar to previous category but with a bankfull that differentiates the ordinary flooding zone from the main channel	5	5
Slope of the margins between 45◦ and 75◦, with or without steps	3	3
Slope of the margins between 20◦ and 45◦, with or without steps	2	2
Slope of the margins <20◦, large riparian zone	1	1
Presence of one or several islands in the river		
Width of all islands ≥5m	-2	
Width of all islands <5m	-1	
Percentage of hard substrata that can make impossible the presence of plants with roots		
>80% 60-80% 30-59% 20-29%	N/A +6 +4 +2	
Total Score		

Geomorphical type according to the total score

>8	Type 1	Closed riparian habitats. Riparian trees, if present, reduced to small strip. Headwaters.
5-8	Type 2	Headwaters or midland riparian habitats. Forest may be large and originally in gallery.
<5	Type 3	Large riparian habitats and potentially extensive forests. Lower courses.

Tree Species in Riparian Area:

Native Species	Non-native Species

Shrub Species in Riparian Area:

Native Species	Non-native Species

Notes: ____